McMILLIN BRIDGE **HAER No. WA-73**

(Puyallup River Bridge)
State Route 162 spanning the Puyallup River
McMillin
Pierce County
Washington

HAER
WASH
27-MCMIL,
1-

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

PHOTOGRAPHS

REDUCED COPIES OF MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

HAER
WASH
27-MCMIL,
1-

HISTORIC AMERICAN ENGINEERING RECORD

MCMILLIN BRIDGE
(Puyallup River Bridge)

HAER No. WA-73

Location:	State Route 162 spanning the Puyallup River, McMillin, Pierce County, Washington, beginning at mile point 6.81.
	UTM: 10/558030/5219340
	Quad: Lake Tapps, Wash.
Date of Construction:	1934
Engineer:	Homer M. Hadley, Portland Cement Association, major layout and design. W. H. Witt Company of Seattle, detailed drawings
Fabricator:	Dolph Jones, under the direction of the Pierce County Engineer's office.
Owner:	Washington Department of Highways. Since 1977, the Washington State Department of Transportation, Olympia, Washington
Present Use:	Vehicular and pedestrian traffic
Significance:	This is a rare example of a reinforced-concrete through truss bridge. The form of its members and details are unique. At the time of its construction it was thought to be the longest concrete truss or beam span in the country. It has been placed on the National Register of Historic Places.
Historian:	Wm. Michael Lawrence, August 1993

History of the Bridge

Washington's varied landscape, with its mountains, its rivers, and its canyons, has presented bridge engineers with many challenging opportunities. Many of their designs have been constructed of reinforced-concrete. A most unusual example spans the Puyallup River in Pierce County. It is a through Pratt truss, a type very common among steel bridges, but very rare in reinforce-concrete. The chords and endposts are U-shaped and the intermediate posts or verticals are H-shaped in section. A walkway passes through each of the 7' wide trusses, by means of openings in the middle of each vertical. Each opening is rectangular with truncated corners at the top. Above it is another hole shaped like an irregular octagon. These shapes and openings contribute to the startling appearance of this bridge.

Although this is not the only reinforced-concrete truss ever built, there does not seem to be any clear precedent for the unusual form of this particular structure. Indeed, concrete trusses of any sort are uncommon. A search of American professional engineering journals will discover only a few articles concerning examples, in bridges or other uses.

Two 1916 articles in a series published by the trade journal *Concrete* discuss concrete roof trusses. The first described how engineers and architects were just beginning to accept such structures, having "turned a deaf ear to even the mention of the possibility of such construction,"[1] and presents examples in a variety of configurations. The second article dealt with theory and detailing, and discussed designs discussed in the article feature chords, posts, and diagonals that are rectangular in section for the most part.[2]

With regard to examples of bridges, a through "bowstring girder" in Dover, England featured diagonals and verticals in an arrangement similar to a multiple King Post truss with a curved upper chord.[3] A deck "truss" built in 1922 at Randan, France was as unusual as the McMillin Bridge. It consisted of horizontal chords and verticals without any diagonal members. Steel X-frames or reinforcing in the posts prevent deformation and the openings in the concrete were elliptical.[4] Although this bridge is an experiment as radical and unusual as the McMillin Bridge, neither it nor the truss at Dover would serve as a model for the American bridge.

Two bridges built in Seattle may have inspired the creator of the McMillin Bridge. They were much simpler, however, with square section members rather than the complicated forms of the chords and posts at the McMillin Bridge. In 1928, A. W. Munster, of the city bridge engineering department, designed an 80' long deck truss similar in elevation to a Warren truss bearing on tall concrete bents. The bents were octagonal in section. This truss was part of the Admiral Way Bridge in Seattle.[5] Three years later he and his assistant, Clark Eldridge, would design the 3,000′ West Garfield Street viaduct, using similar trusses and bents.[6]

Munster had an admirer, a younger man named Homer M. Hadley, who was regional structural engineer in the Portland Cement Association Seattle district office and whose job was to promote the use of concrete in public structures. Hadley seems to have been quite impressed by Munster's designs. In one of many articles he wrote during his career, he discussed how the reinforced truss was common in Europe, but a novelty in America for its expensive formwork and difficult placement in the small members. Munster was willing to build such structures, however, because of his early European experience. Hadley concluded his discussion by noting how Munster designed the viaduct at the age of 75, and that:

> Perhaps the most remarkable thing of all about this bridge is not its unusual structural features but what it reveals of the mental freshness, vigor, and confidence possessed by its designer at the end of a full life, and after a wide and ripe experience.[7]

Homer Hadley, who would be responsible for a number of innovative bridge designs during his own career, probably wished to see himself in a similar manner.[8] Shortly after writing this article in 1932, Hadley had his own opportunity to experiment with concrete trusses when Pierce County decided to build a new bridge over the Puyallup River. The resulting structure differed considerably from Munster's.

At its conclusion, two of the engineers involved in this project, George Runciman, of the Witt Company, and W. E. Berry, Pierce County Engineer, wrote an article published in *Engineering News-Record*.

They wrote that in the winter of 1933-34, a flood undermined the abutment of the existing 150′ steel span, called the McMillin Bridge, over the Puyallup River. Pierce County decided to replace the bridge because of its precarious condition and its narrow, 16′ roadway with a through truss to not interfere with the unpredictable Puyallup River. It would be 20′ longer than the existing bridge, and would have 20′ approaches, with piers down to 15′ below grade supported on H-piles.

The county had two designs prepared for the bridge, one to be built of steel and the other of concrete. "The steel was of the standard type, commonly used for light highway work" with a 24' roadway, a lateral clearance of 25'-6", a vertical clearance of 16', and no sidewalks.[9]

The drawings for the concrete alternative are dated from 26 June 1934 and 16 July 1934, and as they closely match the executed structure.[10] As money received from the state was used, the Washington Department of Highways had to approve the design.

Berry and Runciman wrote that "the major features and layout of this [concrete] bridge were suggested by Homer M. Hadley, regional structural engineer of the Portland Cement Association. The W. H. Witt Co., Seattle, prepared the detailed plans."[11] They do not make it clear, however, just when Homer Hadley and the W. H. Witt Company became involved.

The county opened the bids on 23 August 1934--six for the steel design ranging from $36,738 to $48,250 and one for $35,912 for the concrete design. According to Berry and Runciman, "the lateness of the season and the hazard of fall floods deterred several contractors from quoting on the concrete."[12] They do not explain why, but this is probably because the shoring, formwork, and pouring procedures for a concrete bridge would be much more vulnerable than shoring for a steel truss. Dolph Jones of Tacoma was the low bidder and submitted the lone proposal for the concrete structure.

The drawings indicate that a temporary wooden trestle was to be built next to the site of the old bridge and the one that would take its place.[13] Instead, the steel span was moved 35' downstream and was set on wooden approaches. Work then commenced, in September. Fears of the contractors who submitted bids for the steel truss design came true. In October a heavy flood halted work until the following April.[14]

A collection of photographs survives which provide a visual record of the progress of construction in the spring and summer of 1935. It also provides information about the construction procedures involved.[15]

By 20 May 1935 the contractors completed the reinforced-concrete piers and approach at the south end, having stripped off the forms.[16] The construction of the falsework for the main span followed. This consisted of pile bents. According to Berry and Runciman, these were located at the truss panel joints,[17] which is not obvious in the photographs. Freshly cut trees with the bark still on them served as piles. These supported massive timbers laid crosswise under the formwork. The timbers carried wood joists, perhaps 2" x 12", laid in the direction of the roadway. Shims consisting of piles of wood blocks under the bearing points of the joists brought them up to the proper elevations. The formwork, consisting of wood boards, was laid on these joists. A photograph dated 15 June shows most of the formwork for the deck in place.[18]

Asahel Curtis, a noted regional photographer, captured the scene on 27 June and four of his large format photographs from that date survive.[19] The formwork for the deck and lower chords was complete and the reinforcement for the deck, lower chords, and diagonal members was in place. According to Berry and Runciman:

> The reinforcement of the truss diagonals, anchored and bonded into the bottom chord, was supported in correct position on light wooden frames, longitudinally and transversely braced while the concreting was being done. Steel for the verticals and end posts was stubbed into the concrete. Mixing was performed with a 2-sack machine on the south approach span. The entire deck--roadway and bottom chords of trusses--was placed in one continuous pour of 254 cu. yd.[20]

This was in the days before there were large concrete mixing plants and delivery trucks which could travel long distances and keep cement, aggregate, sand, and water well mixed. The contractor was obliged to set up his own plant at the south end of the bridge, with stacks of cement bags protected from the region's frequent rains by tarps and large piles of sand and stone.

One of the four photographs depicts the process quite nicely. The mixer stands on the south approach span with one man operating it while two others measure the proper quantities of gravel and sand in wheelbarrows. Another pushes a barrel filled with concrete down a plank runway to the opposite end of the bridge where the pour is beginning and will proceed towards the mixer.[21]

According to Berry and Runciman, the end posts and verticals constituted the second pour, top chords the third, and diagonals the fourth.[22] This sequence had to do with the design of the trusses which required that the diagonals should be poured last so that the reinforcing steel within them would carry practically all stresses due to the dead load of the bridge.[23] Otherwise, the diagonals would stretch and the concrete encasing around these bars would crack.

Photographs of the subsequent work were undated. They depict the fabrication of reinforcement bar cages and part of the formwork for verticals and end posts. In one shot, the boxes that would form the openings in the one of the posts are visible. The reinforcement for the diagonals, however, was left exposed at this stage, since they would be poured last of all, after the top chord. Formwork for the verticals and endposts was of plywood, perhaps because it could be shaped more easily to accommodate the complicated sections and the openings than boards.[24]

Other photographs, dated 22 July, indicate that by that time the formwork for the verticals and the upper chord was largely complete, but with the forms for the verticals left open on one side, perhaps for inspection. The formwork for the top chord was supported by numerous wood wooden studs.[25]

On 29 July the workmen poured the chord. Berry and Runciman describe how the contractor used simple plank runways supported by the top-chord forms themselves, thus eliminating trestling for all runways. Photographs taken on that day illustrate other aspects of the operation. The workmen used a crude elevator to hoist concrete in barrows up to a wooden scaffold bridging the gap between the top chords, at the south end of the bridge.[26] The pour must have commenced at the opposite ends of either truss and as the form was filled, from that end of the form to the other, the planks would be pulled up.

There is no record of just how the diagonals were poured. An inspection of the bridge reveals construction joints below the upper panel points. The uppermost part of the diagonal might have been poured through square holes left in the chords. Square pipes sticking up through the fresh concrete appear one of the photographs of the top chord pour[27] and the top chord still bears the marks left by these temporary openings. One was located just above each diagonal.

Photographs of the bridge dated 13, 20, and 26 August show most of the formwork, except for that of the diagonals, stripped off; the elevator, the curbs along the roadway incomplete except for reinforcement, debris all over the site, and a total lack of construction activity.[28] A final construction photograph, dated 2 September, indicates that the bridge was still closed to traffic, extending this apparent lull in activities.[29] According Berry and Runciman, the bridge was put into service during the same month.[30] Whatever the case, Asahel Curtis made another visit on 17 October, photographing the bridge, complete with curbs, handrails, and wooden decking for the pedestrian ways.[31]

This structure had little if any influence on subsequent bridge designs. In their article, Berry and Runciman proclaimed it as "the longest reinforced-concrete span, exclusive of arches, that has been built to date in the United States." They took pains to point out that its novel design, with broad trusses made overhead lateral bracing unnecessary and by coincidence created covered walkways. In addition, they believed that it was economical because it cost $826 less than the lowest bid on steel, that its design assumptions were correct, that it had a large factor of safety, and that "there were no unusual construction problems." This was the only article regarding this structure published in any engineering or contracting journal.

Homer Hadley, who is credited with the conceptual design of the McMillin Bridge, did not mention it in any of his articles. He may have been responsible for the design of another reinforced-concrete truss, to be built as the Limekiln Bridge in Pierce County. A single sheet of drawings survives for this, a 300' long truss bearing on pier at inner panel points so that the truss cantilevers 50' beyond the piers at each end. The upper chord varies in width from 3' at each end to 7' at the center of the truss. The posts and diagonals are rectangular or square in section, however, unlike the structural members of the McMillin Bridge. Many of the details are similar to those of the McMillin Bridge.[32] This was never built. Hadley apparently did not build any concrete trusses other than the McMillin Bridge.

Another bridge that he and the W. H. Witt Company designed for the Pierce County Engineering Department, the Purdy Bridge, received much more attention from the engineering press. Concrete box-girders such as this one enjoyed a brief popularity in Washington.

As for public reception to the McMillin Bridge, it has quietly served its purpose at its rural site. It received little attention from the press, other than an article in a Tacoma newspaper published shortly after its construction declaring: "It's Longest of Kind in U.S.!--Engineers of Country Interested in New Puyallup Span Near McMillin." The interest, however, was limited to publication of the article in *Engineering News-Record*.[33]

A more recent article in the *Seattle Times* discussed the bridge, which photographer Werner Lenggenhager had discovered, complete with graffiti on the interiors of the trusses. He inquired with the Washington Department of Highways regarding this "peculiar-looking bridge." He wrote, "It is a 'very maverick design...unique to this state, most likely to this nation, and possibly to the world.'"[34]

Design and Description

The working drawings, the construction photographs, and the 1936 *Engineering News-Record* article written by Berry and Runciman make it possible not only to reconstruct its history, but to describe and analyze the McMillin Bridge. The two authors managed to present much information in four pages, and upon examining the structure and considering their explanations, one can realize how much thought, care, and consideration this innovative design required of its creators.

All structural members are made of reinforced-concrete. The bridge consists of three span. At each end is a 20' long slab on longitudinal beams. The main span is a 170' long through Pratt truss with polygonal upper chords. The slabs bear on the embankments and on shelves in each end of the deck supported by the trusses. At its four corners, the main span bears on steel rockers resting on piers.

The deck, its supporting cross beams, and the trusses are monolithic. The deck is between the trusses and is 6-3/4" thick by 24' wide. The roadway on the deck is 22' wide with 1' wide curbs alongside it. The beams are 2' high at the trusses and slightly deeper below the center of the deck, providing the roadway with a crown. The underside of the beams and the lower chords are flush with each other. These floor beams are at 8'-6" on center. They frame into the lower chords at the panel points, which are 17'-0" on center, and into the chord midway between these points.[35]

Each Pratt truss consist of ten panels, each 17' long. The height, measured at the panel points, varies. It is 20' at the center of the truss and dropping to 17'-6" at the ends of the top chord. Each truss is 7' wide. Most other members, except the diagonals, are 7' wide and flush with each other at their outer surfaces. The lower chord, which is 8' wide. The extra foot extends under and supports the deck.[36]

The chords and endposts are U-shaped in section, or, to put it differently, each consists of a slab with two legs or flanges extending up or down from its edges. The section is similar to that of a steel C-channel. The top chord is a 12" thick slab with 8" thick legs extending 18" below the lower surface of the slab. The lower chord is a 6" thick slab with 8" thick legs extending 2' above the upper surface of the slab. Drains in the slab prevent rainwater from collecting in this chord.[37] The slanting endposts are similar in section. Each consists of a 6" thick slab with 2'-wide flanges extending 18" from the lower surface of the slab, that is, the surface facing toward the center of the bridge.[38]

Each vertical or intermediate post is like an I-beam in section, with a web and two flanges. Each post is perpendicular to the axis of the truss and the outer surfaces of the flanges are flush with the outer surfaces of the chords, except at the deck. This is where the legs of the lower chord are located under the deck.

The flanges are 8" thick and 2' wide. The webs are 8" thick.[39]

Each web is pierced by two openings. At the lower end is a 3' wide by 7' high opening.[40] It is rectangular with truncated upper corners. Similar openings pierce the endpost. Directly above is another opening, of the same width but with different heights at the various posts. It is octagonal with unequal sides. The openings lighten the posts. A wooden deck, flush with the top of the lower chord and the deck, fits into this chord. Pedestrians may walk down this deck and through the openings.

There is a pair of diagonals in each panel, flanking the pedestrian walkway. Each diagonal is 8 1/2" thick and 16" wide, with the long sides perpendicular to the axis of the truss. These frame into 45 degree fillets at the panel points, located between the flanges and the openings in the webs of the posts.[41]

The trusses bear on the piers by means of steel rockers. Each rocker is shaped like an I-beam in section. At one end of the bridge, the upper surface of the rocker is curved, while at the other end, both top and bottom are curved.[42]

Four reinforced concrete piers support this structure, one under each bearing point. In section they are irregular octagons, stepping back from top to bottom. The piers are in pairs, at each end of the bridge, and each pair is joined by thin reinforced concrete spandrel beam. They rest on footings, which are also irregular octagons in plan. These bear on steel H-piles.[43]

In a Pratt truss, the loads from the deck are carried by cross beams framing into the chord at the lower panel points and midway between these points. The loads on the lower chord, dead and live, are transferred by the diagonals, acting in tension, to the upper panel points. The posts, acting in compression, transfer these loads to lower panel points. The loading is cumulative, from the mid-span to the ends of the trusses, resulting in increased stresses and strains. Unlike the rest of the posts, the hip verticals next to the inclined endposts acts in tension rather than compression. They serves as a hangers for the chord at this part of the truss. The inclined endposts, acting in compression, transfer the cumulative loads to the bearing points and piers. The upper chord, acting in compression, counteracts the tendency of the endposts to lean inward, and the lower chord, acting in tension, prevents the lower ends of the posts form moving outward. In a reinforced-concrete truss, the behavior of the forces in these members helps determine the reinforcement of the concrete. This is because concrete is strong in compression but weak in tension, while steel is strong in both.

The reinforcement in the floor beams is located at the bottom of each beam where the tensile forces are greatest. These bars terminate inside the lower chords and some extend all the way to the outside of the trusses. In the beams located at the panel points, some of the bars are bent up into the webs of the posts. This effectively secures the beams to the trusses.[44]

As the diagonal must resist tension, the reinforcement must be securely anchored to the chords at the panel points. The upper end of each bar is bent in a gentle curve, so that the last foot or so is parallel with the top chord. This is true of all the diagonals except for those at the end, where the upper ends are in the form of hooks. The concrete is enlarged and squared off at these points to accommodate the hooks. The lower end of each diagonal is also hooked.[45] These diagonal bars are not welded or fastened to the reinforcing bars of the chords or verticals. In their article, Berry and Runciman explained that anchorage of the diagonals is obtained by bond alone, which is accomplished by extending the bars at least 40 bar diameters past the point at which the diagonals meet the fillets, by using large bends and sweeps at the ends of all diagonals, and by the clamping compressive effect which the pressure from the verticals produces.[46] The amount of steel in the diagonals is greater the closer they are to end of the truss.[47] This is because of the cumulative increase in the tensile forces.

Reinforcement of the vertical posts is different. The flange of each post contains a reinforcing bar cage which is a "T" in section, with the leg of the Tee fitting into the web. Hoops around the bars held them in position relative to each other before the concrete was poured. The bars and hoops help resist the tendency of compression forces to burst the concrete outward. The bars do not require the sort of anchorage that the diagonals do, therefore their ends are not hooked. This is also true of the bars in the vertical posts next to the endposts, even though they act in tension. This is because they do not carry loads as great as those carried by the diagonals. The reinforcement of the inward slanting endposts is similar to those of the intermediate posts, except that the cages are square and the upper ends of the bars are bent down to make them parallel with the axes of the upper chord.[48]

The layout of the reinforcement in the upper chords consists of bars inside hoops. The bars are not fastened together where they overlap at their ends. The 1-1/2" square bars in the lower chords are a different matter. Because the lower chord acts in tension, the bars must be continuous for the entire length of the chord. Therefore, the bars were butted at their ends, with 2-1/4" x 1/2" x 9" plates welded to either side. According to Berry and Runciman, mid-span bars which did not have to extend through to the supports were terminated by extending them at least 5' beyond the panel point where they ceased to be needed, and then welding them to adjoining bars. The bars were anchored at the ends of the chords by bending each in a full semi-circular sweep up to the top of the chord and then returning them downward to the bottom at an angle of about 30 degrees directly beneath the main end posts of the truss. The bars from the posts are interwoven with these large hooks. The concrete extends 30" beyond the joint to accommodate the hooks.[49]

In their article, Berry and Runciman explained that the design of the bridge was based on the assumption that the trusses were loaded axially. This assumption:

> . . . departs from actuality in the fact that although 60 per cent of the dead load is in the trusses, the remaining 40 per cent is in the roadway. This roadway dead load, together with the live load, is delivered to the inner side of the trusses. This eccentricity is real and unavoidable and is not to be circumvented merely by designing the floor beams on an assumed span c. to c. of trusses. Recognizing this condition, the reinforcement of the panel-point floor beams was extended to the outer side of the trusses, diagonal steel was provided over the doorway openings in the verticals, and then the assumption was made.[50]

The diagonal steel about which the authors wrote consists of crossed reinforcing bars within the webs of the posts. There are actually two sets of crossed bars, one just above the lower opening or doorway and another set above the upper hole. The concrete was formed to fit around this reinforcement resulting in the irregular shapes of these openings.[51]

The photographs and drawings indicate that the reinforcing consisted of both deformed round and square bars (with upsets or raised surfaces). At the time this bridge was built, bars less than 1 inch thick were usually round, while the larger ones were square. This was because square bars were easier to roll in the larger dimensions. The round bars, as well as the upsets or raised parts of the surfaces were relatively new developments. In earlier times, builders used smooth square bars. Not only were they easier to roll, but they were less likely to twist within concrete than round ones.[52] The McMillin Bridge, therefore, represents a transition in reinforced concrete design and construction practices.

According to Berry and Runciman, the bridge was designed based on the assumption that "joints of the truss were free and without restraint." Construction joints at the top and bottom of the posts offered the opportunity for slight elastic adjustments. The diagonals were poured last of all, after the shoring was removed and they were "subjected to practically their full stress by dead load." In addition, the engineers "anticipated that deflections would be slight."[53] The concern here was the possibility that the forces in the truss would cause deflections such as the tendency of the posts to buckle due to compression or the diagonals to stretch due to tension, that could crack the concrete.

The construction joints could allow moisture to seep in and rust the reinforcing bars. It was undoubtedly for this reason the drawings stipulated that "in trusses all bars passing thru [*sic*] construction joint shall be given a heavy coat of asphalt paint for a distance of 2" ea. side of joint."[54]

The trusses bear on the piers by means of rockers, through steel plates fastened to the underside of the concrete. Each rocker is shaped like an I-beam in section. At one end of the bridge, the fixed end, the rockers have curved upper surfaces, allowing rotation due to deflection but not lateral movement due to expansion. The rockers at the other end are curved at top and bottom, accommodating both deflection and expansion. These rockers are cadmium-plated to guard against corrosion.[55]

According to Berry and Runciman, they and other engineers designing this structure were not entirely happy with the use of these "steel bearings and rockers of conventional design . . . as required," and had wanted to use asbestos packing between metal plates. They believed these would have been much less expensive, would have accommodated any movements, and would have been much more suitable in an earthquake.[56] They did state who required the conventional rockers. The state highway department, the agency providing funds and consequently reviewing the design, may have stipulated using conventional rockers. Such a minor disagreement was not unusual, in an age when bridge and highway design was increasingly complicated by the involvement of more than one governmental agency.

Berry and Runciman also explain that the wide trusses would have greatly increased the up and downstream dimensions of conventional piers and consequently, the equivalent of individual pier shafts was built for each truss, and these companion shafts at each end of the span were joined at their tops by deep connecting diaphragms. Steel H-piles were driven to 25′ below grade at the south end to support the footings. During construction, the soil proved to be softer than expected, and the piles at that end were driven 40′ below the footings and additional wood piles were driven into the soil as well.[57]

The two authors also provided information about the concrete used in this bridge. The unprecedented length of span required that dead load be kept to a minimum. For this reason, a "Special Class A" concrete was used in the deck and top chord, where stresses were higher. It consisted of a richer mix of concrete with 2 barrels of cement per cu. yard with a flexural working stress of 1,200 lbs. per sq. in and a direct stress of 900 lbs. per square inch. Elsewhere, the standard "Class A concrete" was employed, with 1.81 barrels of cement per cubic yard and an assumed cylinder strength of 3,000 lbs. at 28 days, a maximum stress of flexure of 1,000 lbs. per square inch. Aggregate with a maximum size of 3" was used in the piers and 1-1/2" everywhere else.[58] The smaller aggregate would have been required in the trusses, where it had to slip through much more complicated forms and arrangements of bars.

The design and form of the bridge is unique. Steel through trusses are common. Reinforced-concrete versions are very rare. Most of those few that have been built are much less than 7' wide and have rectangular sectioned chords and posts rather than structural members which are U-shaped or I-shaped in section, with holes in them. Although many bridges have sidewalks next to the roadway or cantilevering beyond the trusses, walkways passing through the trusses, as in the case of the McMillin Bridge, are exceptional.

Many of the details and techniques employed in this structure, such as reinforcing bars with hooked ends, bars that are welded together, criss-crossed bars, construction joints, and pouring concrete in a sequence intended to avoid cracking are not unique to this bridge. Using them in a truss, however, especially one with members of such unusual sections, was hardly a standard practice. The engineers were obliged to give careful thought and consideration to the use of these practices in this unprecedented structure. The McMillin Bridge, therefore, is not only a rare example of a reinforced-concrete through truss but is also demonstrates what such an experiment can entail.

Repair and Maintenance

The bridge has stood up well over time with little deterioration of the concrete other than minor cracking and spalling. Some of the reinforcing bars in the vertical posts are exposed, probably due to inadequate cover, and they are rusting slightly. The upper chords of the trusses seems to be giving them some protection from rain.

Maintenance has consisted of placing new rip-rap in 1950, repainting the rockers on occasion, and replacing the wooden sidewalks in 1960 at a cost of $3,756.38.[59]

Data Limitations

This report depended on three main sources: copies of the drawings for the bridge, the 1936 *Engineering News-Record* article written by Berry and Runciman and an album of construction photographs discovered at the office of the Washington State Department of Transportation's Bridge Preservation Section in Olympia. These sources provided a great deal of information which made it possible to describe and analyze the structure. Because some of the photographs were dated, it was possible to reconstruct the construction history and procedures used.

Research of newspaper coverage depended on collections of clippings at the Washington State Library in Olympia, the Washington State Historical Society library in Tacoma, and the Tacoma Public Library. Newspaper coverage of the project was minimal, which is not surprising, since the bridge was built at an isolated rural site. Obituaries and biographical information

was also available for some of the men involved in the project, especially Homer M. Hadley.

Project Information

This project is part of the Historic American Engineering Record (HAER), National Park Service. It is a long-range program to document historically significant engineering and industrial works in the United States. The Washington State Historic Bridges Recording Project was co-sponsored in 1993 by HAER, the Washington State Department of Transportation (WSDOT), and the Washington State Office of Archeology & Historic Preservation. Fieldwork, measured drawings, historical reports, and photographs were prepared under the general direction of Robert J. Kapsch, Ph.D., Chief, HABS/HAER; Eric N. DeLony, Chief and Principal Architect, HAER; and Dean Herrin, Ph.D., HAER Staff Historian.

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APPENDIX

The designers and builders

Research for this report uncovered some information regarding the men who designed and built the McMillin Bridge.

The major features and layout were suggested by Homer M. Hadley, regional structural engineer of the Portland Cement Association. The W.H. Witt Company of Seattle, with George Runciman as president, prepared the detailed drawings. W. E. Berry was the Pierce County engineer during the time when the bridge was designed and the county awarded the contract Dolph Jones. Forrest R. Easterday was county engineer during the construction period. The resident engineer was F. W. Walters.[60]

George Runciman, who, with W. E. Berry, authored the 1936 *Engineering News-Record* article, was a leading structural engineer in Seattle. He was a graduate of the University of Idaho and received a Bachelor of Science degree in Civil Engineering from the University of Washington in 1924. He engineered the structural design of many Seattle buildings, including the Grosvenor House, the Vance, Lloyd and Logan Buildings, and the Health Sciences Building at the University of Washington. He died at on Sunday, 12 September 1965, at the age of 73.[61] Runciman and his company were involved in the design of other innovative reinforced concrete structures, also built by Pierce County, such as the Purdy Bridge (1936, HAER No. WA-101), the Eatonville Bridge (1936), and the Buckley Overpass (1936). These were concrete box girders conceived by Homer Hadley. The W.H. Witt Company is still in business, having changed names and ownership several times. Today it is known as Skilling, Ward, Magnusson, Barkshire, Inc.[62]

Forest R. Easterday was born in Tacoma, of a pioneer family, and lived there most of his life. He was a state legislator, a Pierce County Commissioner and County Engineer, and served on the Tacoma City Council from 1958-62. He also worked on government projects in Alaska and South America. He died in 1964, at the age of 75.[63] Easterday was author of several articles regarding concrete box-girder bridges in Pierce Co., including the Purdy Bridge.

Dolph Jones was "one of Tacoma's pioneering contractors," being in the contracting business beginning in 1900. He was born in Fortville, Ind., and moved to Wilkenson, Washington, in 1899, then to Tacoma in 1916. He was contractor for a number of educational and institutional buildings in the Puget Sound area. He died at the age of 90, in 1968.[64]

Homer More Hadley is a figure of regional if not national importance in engineering history. He was the inspiration and, in some cases, the designer, for a number of innovative projects. Hadley was born in Cincinnati, Ohio, 15 November 1884, son of George William Childs and the former Elizabeth More. He studied engineering for three years at the University of Washington. During the early phase of his career, he worked with a number of surveying crews, in North Dakota, with the U.S. Coast and Geodetic Survey in the Mojave Desert, along the Oregon Coast, for the Great Northern Railroad at Index, Washington, for the Copper River Railroad in Alaska, and for the Canadian Northern Railroad on Vancouver Island. During World War I he designed concrete ships for the Emergency Fleet Corporation in Philadelphia--an experience that was a source of inspiration for his most famous innovation, the concept of a reinforced concrete floating bridge. In 1921 he joined the Portland Cement Association at its district office in Seattle, as an engineer promoting the use of concrete in public structures. This position brought opportunities to involve himself in projects throughout the Northwest, if only at the conceptual design phase. He resigned from the association in 1947 to enter private practice as a structural engineer in Seattle and he was active until his death.

Hadley designed or helped design numerous bridges. These included a several in reinforced concrete box-girder bridges in Washington, beginning with the first such structure built in the United States near Eatonville (1936), the Buckley Overpass near Buckley, the Purdy Bridge, thought to be longest in country when built, and the Terrace Heights Bridge, over Yakima River in Yakima County (1939). Around 1920, Hadley conceived the idea of a concrete pontoon bridge over Lake Washington, just east of Seattle, and spent years promoting the idea. Such a structure was finally built in 1938, the Lake Washington or Lacey V. Murrow Floating Bridge (HAER No. WA-2).

Hadley proposed a bridge over the Puget Sound in 1951[65] and helped promote the idea when public debate over the project began in the late 1950s.[66] He was an early user of precast concrete slabs in bridges an of so-called bundled-bars for reinforcement and in 1951 designed an early steel box-girder, the Portage Canal bridge near Port Townsend, Washington. At 250', it was the longest such structure in the United States at the time it was built.[67]

Hadley also designed the Benton City-Kiona bridge in eastern Washington State, which was the first tied-cantilever bridge of its type in the nation.[68] His Parker bridge, in Yakima County, Washington, won the American Institute of Steel Construction's first prize in 1962 for the most beautiful short span bridge in the United States in 1962, which embodied his "delta-girder system."[69] Late in life he became interested in combining prestressed concrete flanges with steel webs in the design of bridge girders.

Hadley also pursued other engineering design avenues. He patented one of the first concrete paving machines in the United States in the 1930s. He was interested in earthquake resistant design. He held patents on other inventions besides the paving machine, including several concerning construction beams. His avocations included geology, history, and literature.

Hadley was author of numerous articles. He received a Certificate of Award from the James T. Lincoln Arc Welding Foundation (July 1966), was a member of the American Society of Civil Engineers, the American Concrete Institute, and the Structural Engineers Association of Washington. He was first president of the Seattle chapter of the Engineer's Club.[70]

In his late years he was just as vigorous as ever working well into those late years. Over 30 years before, he had written of 75-year old A.W. Munster's Garfield Street viaduct:

> Perhaps the most remarkable thing of all about this bridge is not its unusual structural features but what it reveals of the mental freshness, vigor, and confidence possessed by its designer at the end of a full life, and after a wide and ripe experience.[71]

Hadley, no doubt, saw himself in a similar manner, well into his old age. Hadley drowned on 6 July 1967, while swimming in Soap Lake, in central Washington.

Some people in Hadley's adopted state still remember him as a "free spirit" and as a pioneer and innovator. He was posthumously recognized in 1993, when the new Interstate 90 concrete pontoon bridge, which was built alongside the original Lake Washington floating bridge, was named in his honor.[72]

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Photograph Album, c. 1935, with construction photographs of the Purdy and McMillin Bridges. Held by Bridge Preservation Section, Washington State Department of Transportation, Olympia, WA [WSDOT].

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"It's Longest of Kind in U.S.!" *Tacoma News-Tribune*, 22 January 1936), 1.

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ENDNOTES

[1] Albert M. Wolf, "Reinforced Concrete Roof Trusses--Types in Use - Design Methods," *Concrete* 9 (June 1916): 251.

[2] "Reinforced Concrete Roof Trusses--Part 2, Theory and Details of Design," *Concrete* 9 (June 1916): 13-18.

[3] Major Johnstone-Taylor, "Some Recent British Concrete Bridges." *Concrete* 24 (July 1923): 26-27.

[4] "Concrete Continuous-Truss Bridge Without Diagonals," *Engineering News-Record* 89 (30 November 1922): 926.

[5] "Steel Plates Transfer Stress in Concrete Bridge Truss." *Engineering News-Record* 100 (15 March 1928): 440-41.

[6] Clark H. Eldridge, "Concrete Trusses and 47-ft. Flat Slabs in New Seattle Viaduct," *Engineering News-Record* 106 (16 April 1931): 642-44.

[7] Homer Hadley, "Garfield Street Bridge at Seattle," *Western Construction News and Highway Builder*, 10 April 1932, 176.

[8] For a discussion of Homer M. Hadley's career, see Appendix.

[9] W. E. Berry and George Runciman, "Through Concrete Trusses, 170 feet Long Used on Low Cost Highway Bridge," *Engineering News Record*, 2 January 1936, 1.

[10] W. H. Witt Company of Seattle. "Secondary Highway No. 22--Bridge No. 1319 over the Puyallup River--Alternative Plans Concrete Span," 26 June 1934 (Sheets 1 to 5) and 16 July 34 (sheet 6), held by Records Control, WSDOT.

[11] Berry and Runciman, 4.

[12] Ibid., 2.

[13] W. H. Witt and Company, sheet 1.

[14] Ibid.

[15] Photograph Album c. 1935, with construction photographs of the Purdy and McMillin Bridges, held by Bridge Preservation Section, WSDOT.

[16] Ibid., photograph of piers (dated 20 May). The temporary trestle is in the background, which was located to the east of the piers.

[17] Berry and Runciman, 4.

[18] Photograph Album, photographs dated 7 and 15 June.

[19] Photograph Album, photographs dated 27 June. The photographs bear Asahel Curtis's monogram and are labelled Nos. 61250, 61252, 61253, and 61254. These are not in the Asahel Curtis collection at the Washington State Historical Society Library in Tacoma, WA. No. 61250 (figure 3 in the Berry and Runciman article) is an oblique shot of the shoring and formwork. No. 61252 depicts the pour of the lower chords and floor. No. 61253 (figure 4 in the Berry and Runciman article) is a closeup of the formwork and reinforcement for one of the lower chords. No. 61254 is a closeup of the formwork and reinforcement of at the end of a lower chord.

[20] Berry and Runciman, 4.

[21] Photograph Album, Asahel Curtis No. 61252.

[22] Berry and Runciman, 4.

[23] Ibid., 2.

[24] Photograph Album, photographs undated. One of the photographs, which depicts the reinforcement and partially completed formwork for one of the posts, is identical with figure 5 in the Berry and Runciman article.

[25] Ibid., three photographs, one of the reinforcement and formwork for the end post and two of the same for the top chords, dated 22 July.

[26] Ibid. Three photographs dated 29 July. The photograph of the elevator appears in the Berry and Runciman article as Figure 6.

[27] Ibid.

[28] Ibid., photographs dated 13, 20, and 26 August.

[29] Ibid., photograph dated 2 September.

[30] Berry and Runciman, 2.

[31] Ibid., photograph dated 17 October. Asahel Curtis No. 61557. This was not found in the Asahel Curtis Collection at the Washington State Historical Society.

[32] Pierce County, WA. "Limekiln Bridge No. 13194 A, Secondary Road No. 3" (1 September 1935). Copy at the Pierce County Public Works Department Bridge File. The drawing is in the same folder as the file for the McMillin Bridge.

[33] "It's Longest of Kind in U.S.!" *Tacoma News-Tribune*, 22 January 1936, 1. The article is accompanied by the 17 October 1935 Asahel Curtis photograph of the finished bridge, complete with his name and the photograph number in the corner.

[34] "An unusual bridge spans the Puyallup River at McMillin," *Seattle Times*, 8 September 1971, A-11. The author added, "That makes it a pretty special bridge. So try to improve on the quality of the graffiti."

[35] This description is largely based on the drawings by the W. H. Witt Company, sheets 2 & 3.

[36] Ibid., sheet 2.

[37] Ibid., sheets 2 and 4. See also, Berry and Runciman, 2.

[38] W. H. Witt and Company, sheet 2.

[39] Ibid., Section A-A and details for verticals, sheet 4.

[40] Ibid.

[41] Ibid., elevation of Truss and Transverse Section, sheet 2. See also, Berry and Runciman, figure 2.

[42] Ibid., bearing details, sheet 3.

[43] Ibid., sheet 6. See also, Berry and Runciman, 3.

[44] W. H. Witt and Company., floor beam details, sheet 4.

[45] Ibid., sheet 5.

[46] Berry and Runciman, 2-3. Figure 3 in the article depicts the reinforcing for the diagonals. This photograph is identical a 27 June 1935 photograph in the photograph album at the Bridge Preservation Section, Asahel Curtis No. 61250.

[47] W. H. Witt and Company, details of reinforcement in the posts, sheet 5.

[48] Ibid.

[49] Berry and Runciman, 2. Figure 4 in the article depicts the lower chord reinforcement. It is identical to a 27 June 1935 photograph in the album, Asahel Curtis No. 61253.

[50] Ibid., 2.

[51] The cross-bars are depicted in Berry and Runciman, figure 5. This is identical to an undated photograph in the photograph album at the Bridge Preservation Section.

[52] This information was provided by Hugh Favero, Bridge Inspection Engineer, Bridge Preservation Section, WSDOT.

[53] Berry and Runciman, 2.

[54] W. H. Witt and Company, "Notes" on sheet no. 3.

[55] Ibid., bearing details, sheet 3.

[56] Berry and Runciman, 3.

[57] Ibid., 2.

[58] Ibid., 2. See also, W. H. Witt and Company, "Approximate Quantities," sheet 3.

[59] "McMillin Bridge, No. 162/6," Bridge Inspection Reports, in Correspondence Files, Bridge Preservation Section, WSDOT.

[60] Berry and Runciman, "Through Concrete Trusses, 170 feet Long Used on Low Cost Highway Bridge," *Engineering News Record*, 2 January 1936, 4.

[61] "George Runciman," *Seattle Times*, 14 September 1965, 20.

[62] The company was traced down using *Polk's Seattle City Directory* (Seattle: R. L. Polk and Co., 1934 to 1993). Mr. Barkshire referred me to Mr. Harold Worthington, former president

of the company and secretary-treasurer when the McMillin Bridge was built. Mr. Worthington is now 92 years old. When asked about the bridge, Worthington said he had little to add to what was written in the *Engineering News-Record* article.

[63] "Forrest R. Easterday," *Olympia Daily Olympian,* 27 February 1964, 2.

[64] "Dolph Jones, 90, Pioneer Tacoma Contractor, Dies," *Tacoma New Tribune*, 18 February 1968.

[65] Homer M. Hadley, "A Trans-sound Bridge at Seattle, Washington," *Puget Sound Engineering* 6 (January 1951): 1-3.

[66] "Hadley backs Bainbridge Sound Span," *Seattle Times*, 3 March 1959, 2.

[67] "H. M. Hadley Dies; Bridge Designer," *Seattle Post-Intelligencer*, 7 July 1967, 43.

[68] Ibid.

[69] "Seattleite's Bridge Design Award Winner," *Seattle Times*, 22 December 1963, 16.

[70] "Hadley, Floating-Bridge Proposer, Dies in Lake," *Seattle Times*, 6 July 1967, 55.

[71] Homer Hadley, "Garfield Street Bridge at Seattle," *Western Construction News and Highway Builder*, 10 April 1932, 176.

[72] "Floating bridge to bear name of innovator Hadley--Interstate 90 span to be dedicated today," *Seattle Post-Intelligencer*, 17 July 1993, B-1. Unless noted otherwise, the information for this biography is from "Hadley, Homer More," *The National Cyclopedia of American Biography*, vol. 54 (Clifton, New Jersey: James T. White & Company, 1973), 354-55.